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The Impact of Mislabeling in Manufacturing: A Case Study from an Automotive Supplier Industrialization Internship

Ganpati Goel
Tesla Inc., Palo Alto, California, USA

ABSTRACT

Manufacturing industries like automotive manufacturing can incur enormous operational disruptions, financial losses, and safety hazards from mislabeling in manufacturing. This paper applies a case study based on an automotive company's Supplier Industrialization Internship program to examine the effects of mislabeling. This study analyzes real-world mislabeling incidents, focusing on the abnormal process of Supplier Corrective Action Request (SCAR), which is used to identify and correct mislabeling errors and prevent future problems. These were clichéd root causes of traceability that data-driven insights were instrumental in tackling: overproduction of labels, misinterpretation of traceability requirements, and operator errors. Real-time tracking, data analytics, and automation helped label accuracy and efficiency. Corrective actions were using the dual scanning system to verify the label's correctness, elaborating on the training programs, and changing the labeling process. The paper also highlights the importance of continuous improvement, supplier collaboration, and adopting advanced labeling technologies like QR codes and RFID tags to avoid mislabeling. The second phase focused on a strong organizational culture based on quality and using Lean Manufacturing and Six Sigma principles to continue to reduce labeling errors. This study concludes with a broader scope in that it underlines the importance of consistent and data-driven labeling practices for increasing product quality, operational efficiency, and safety standards while minimizing the risks of mislabeling within a large-scale supply network.

KEYWORDS: *Mislabeling, Data-Driven Approach, Automation, Supplier Corrective Action Request (SCAR), Traceability, Quality Assurance*

1. Introduction

Manufacturing mislabeling means wrongly labelling products as a component, having a tag associated with the components, wrongly labelling an entire product, or wrongly tagging a particular piece of material. Even though it is a seemingly small error, it is an error that has significant and broader impacts. Effects of labelling misbranding can compound throughout the manufacturing process, resulting in production delays, quality problems, increased scrap rate, and operation inefficiencies. One industry that relies on precision for success and is a major reason for precision manufacturing is automotive manufacturing. Even the slightest misstep can bring about serious safety issues, incur heavy costs, and result in delayed delivery of the products. Especially in the automotive industry, labelling errors are very sensitive because vehicle productions are complex and safety-oriented. By mislabeling, it will spell the mistake of pairing the wrongly matched components with the final product, which becomes unsafe for consumption and does not perform as it should.

The company studied proper labeling as part of a Supplier Industrialization Internship for an automotive company. Those issues were investigated, responded to, and resolved in the company’s manufacturing process. The internship program was to look at real-time mislabeling instances and correct what could go wrong. Solving such issues is one of the key steps the supplier corrective action request (SCAR) process takes. The SCAR process considers defects and quality concerns regarding the supply chain. This process forces suppliers to implement corrective and preventive actions to tackle any errors they find and prevent repeating such errors in the future.

This case study then presents the specific mislabeling situations, the root causes of those situations, and a step-by-step detail of remedies taken to correct each of the mislabeling situations presented in this case study. Besides this, it also makes a broader point of broader impacts on the manufacturing industry. This is not an example of a one-company, one-product line problem. It is a common problem in this industry that can happen in any manufacturing environment, particularly with a complex supply chain of multiple suppliers. This means that the whole manufacturing industry needs to be aware of it and have control over ensuring labeling accuracy and traceability, as the risks of mislabeling are too high. They describe how the automotive company used data-driven approaches to address the data problem of mislabeling and how data analytics was the key to finding and solving that problem. Data-driven decision-making is essential to tracking, identifying, and executing targeted solutions to errors in a modern manufacturing environment. The company found the causes of mislabeling by looking at production logs, operator error reports, and supplier performance data; as it had data, it used empirical evidence to implement corrective actions.

The case study revealed that the major reason for the mislabeling issues was that most of these occurred from human errors, and there were no standard processes in labelling practices. Specific weaknesses in the process were traced to inaccuracies in printing, scanning and applying labels. By using data analytics, these weaknesses were lit, which led to adopting more rigorous training programs, communication with suppliers, automation of the labelling process, and other measures to enhance the labelling process. Barcode scanners, real-time monitoring systems on the production line, and automation of labelling processes were identified as very important pieces to remain error-free in labelling components and materials as they were being manufactured. Advanced data analytics tools were used to provide traceability of products and components, allowing errors in labelling to be easily identified at the beginning stage so these errors could not impact the finished product.

The additional focus of this paper will also include an organizational culture approach for minimizing mislabeling errors. They needed to have a culture of continuous improvement. Employees were encouraged to identify problems and put solutions in place in order to deal with the root causes of mislabeling. Lean manufacturing principles and the Six Sigma methodologies were applied to pull improvements in labelling accuracy and efficiency. The paper discusses collaborating with suppliers to complete the labelling standards like the above. A wider strategy to reduce labelling errors at the source included regular audits and performance evaluations of suppliers.

This study aims to provide insight into how the automotive manufacturer can reduce the risk of mislabeling and how the overall quality of the production process can be best minimized. Effective manufacturers can solve these problems through data-driven decision-making, supplier collaboration, constant improvement, increasing operational efficiency, lowering costs, and improving product safety. This paper will also discuss the use of technology and the necessity of following international standards for labeling products. The paper also demonstrates an automotive company's successful dealing with the mislabeling problem and improving the labeling system through real-life data analysis and case study results.

2. Broader Implications for the Manufacturing Industry

2.1 Operational Inefficiencies

Operational inefficiency in manufacturing is mainly due to mislabeling. Workers tend to spend extra time labeling to identify and correct labeling, so labor delays arise because some components or materials are labeled incorrectly. For example, this would cause severe damage to the assembly line in the automotive field if the parts were mislabeled and the wrong parts were used for vehicle manufacturing. The estimated 5–10 percent delay in production attributed to labeling errors, as suggested in the manufacturing Institute (2021), has implications for inventory scheduling, resource allocation, and delivery schedule (Raju, 2017). Mitigating these inefficiencies with a data-driven approach is possible by identifying labeling error trends such that the root causes of the problem can be solved and the manufacturer can take remedial action before it escalates. With advanced data analytics, they can track such mislabeling incidents when analyzing the data at each stage of manufacturing productivity. It enables manufacturers to reduce the downtime to increase efficiency and throughput.

2.2 Increased Costs

As with many things, mislabeling is often mislabeled as financially less impactful, but not always. Due to incorrect labeling, scrap rates are high, rework costs are high, and the product is and has been recalled in some cases. If a piece is not appropriately set and joins the last cooperation, the piece is an article to be tossed out and the work again, which would incite material cost and work. A 2020 APQC report shows middle-sized manufacturing firms' savings of 1 million dollars because of labeling errors (APQC, 2020). Hiring additional labor to inspect, replace, or rework mislabeled items and losing materials from scrapping the wrong components are two examples of such costs generated by this type of risk. Manufacturers are now often using data analytics to track live scrap and rework costs in order to learn when and how mislabeling most often occurs. Suppose it is acceptable to apply a probabilistic model based on historical data. In that case, manufacturers can use that to take preventative action by changing label verification frequency or adding other robust tracking systems to decrease the overall cost and increase the firm's financial performance.

Figure 1: Mislabeling in FMCG production

2.3 Safety Hazards

It is not simply about manufacturing mislabeling that increases a factory's cost and delays. It is particularly dangerous in industries where product safety is the top priority, such as physicians, food, and manufacturers of automotive products. This may entail the mislabeling of components in the automotive manufacturing field, which may lead to severe product defects in terms of aggravating the safety and stability of an automobile. All of this can result in the wrong labeling of these parts, incorrect use in the wrong applications, or the failure of the structural integrity of the final product. However, automotive components have also been identified as mislabeling of automotive components, resulting in vehicle recalls, which contradicts end-user safety (NHTSA, 2019). Systems labeling and tracing systems can be approached from a data-driven perspective, sufficiently diminishing the risk of such safety hazards. Real-time tracking is another way to track used parts in manufacturing to ensure that every part that goes into production is correctly identified and associated with its specific component (Chen, 2020). Automated label verification systems are also introduced in production so that only the parts containing the labels can be used and no safety issues may occur. Based on these predictive approaches, products can be predicted to be mislabeled, and manufacturers can take action to prevent them.

2.4 Quality Assurance Challenges

Mislabeling is one of the main problems in the quality assurance (QA) process. This mislabeling introduces variability in the production process. Therefore, it can consist of using the wrong components and materials and not finding this, so the final products are of different product quality. It prevents maintaining a high bar when the product supplied matters significantly to customer satisfaction and safety. As per its ISO 9001: 2015 Quality Management Systems, accurate labeling is an effective way of maintaining good quality control, as per the International Organization for Standardization (ISO, 2015). Besides influencing the traceability of the components, mislabeling makes it difficult to maintain the consistency of the product. Suppose the components faithfully, or improperly, label their origin (manufacturer). Manufacturers cannot do reliable inspections or fieldwork audits, as they cannot trace them back to their source (Malsch & Salterio, 2016). Such issues can be addressed by manufacturers using online real-time data-driven quality control systems that monitor labeling accuracy online. Further technologies, such as RFID and IoT sensors, can monitor the labeling process from start to finish to track the labeling process for subsequent labeling pulses to know that components are not being labeled incorrectly and at the right production stage (Chavan, 2021). Installing automated inspection systems ensures that labeling error detection gives the manufacturers a great chance to identify it before it impacts the product quality, thereby guaranteeing labeling per ISO standards and the reliability of the products.

Mislabeling has a wide scope of thinking, and its outcome may range from an increase in efficiency with costs, safety, and quality assurance. The wrong labeling has significant consequences, such as high production delay, lost money, lost life, and poor product quality, and as such, it needs to be addressed. The data can be used to assist manufacturers in identifying the root causes of mislabeling and determining corrective measures to take. Manufacturers can use advanced technologies such as automation, real-time tracking, and information analysis to reduce label error frequency. If today's manufacturing business is to continue for another 100 years, investing in strong marking frameworks and continuous development activities may ultimately benefit efficiency hikes, cost reductions, and extra security standards in the whole manufacturing business.

3. The Role of Technology in Mitigating Mislabeling

Mislabeling in manufacturing costs, wastes time, and jeopardizes safety. In the face of increasingly more complex manufacturing processes, robust systems are inevitably played out to ensure that mislabeling does not occur. Today, the use of automated systems, real-time tracking technologies, and data analysis technology have significantly solved the problem of mislabeling (Woodward et al., 2020). They offer these technologies that make labeling practices accurate, sustainable, and according to industry standards. They prevent human error, which improves operational efficiency.

3.1 Automation in Labeling Systems

One of the best things that can be automated in manufacturing processes is mislabeling. When a sample is labeled, human errors can be caused by factors such as fatigue, distractions, or lack of communication. Using such an automated labeling system, where the machines label the product using parameters that do not vary, eliminates the risks associated with these labels. There are several stages in the production line where these systems can be fitted so that the correct products receive the correct labels with high precision.

Figure 2: Automation in Labeling Systems

Products are labeled in a high-volume manufacturing environment using automation label applicators. These systems are particularly suitable for attaching labels to various products, from small components to large packages, at very low error rates. Integrated vision systems can offer further accuracy in automated labelling systems, verifying the correct label placement before the product continues with the production process. If misalignments or discrepancies are identified, the system can automatically invoke a reapplication of the label or label the product manually for manual review to decrease the risk of mislabeled products progressing to downstream processes. Robotic arms can perform complex labelling tasks, such as labelling on multiple product sides or in difficult-to-reach areas. One advantage of robotic arms is that they are flexible and precise, which is very helpful in automotive manufacturing, where various parts with different shapes and sizes may need to be labelled. Automated systems have proven to be the go-to for manufacturers who desire to produce more label consistency and, even more so, fewer errors (Singh, 2021).

3.2 Real-Time Tracking with IoT and RFID

Integration of Internet of Things (IoT) sensors and Radio Frequency Identification (RFID) technologies with the manufacturing processes has transformed how manufacturers track and verify labelled products. Manufacturers can monitor various aspects of the production process in real-time by using IoT sensors from the status of labelling systems (Nyati, 2018). Introducing RFID technology to these sensors allows these sensors to communicate smoothly with products and systems across the supply chain so that every product is clearly labelled and identified. RFID labels are small, electronically readable labels that store product information. RFID readers can attach and read them at different points along a product's production line. RFID with IoT systems can give us real-time accuracy on the labels among components. When products are chased down through the manufacturing process, RFID scanners read automatically about the composition of products and crosscheck information to alert operators in case of incompatibility. This integration of IoT and RFID technology is not just to ensure that products have the correct labels but to pump up the traceability of products as they are supplied. Taking the automotive industry as an example, all the components in the production to assembly process of an automobile must be correctly labeled and monitored to ensure that the right parts are used at each stage, and incorrectly labeled parts could be very hazardous. These systems can be used for many purposes, but labeling data from them can be analyzed for trends or recurring issues, which manufacturers can cure before they become unmanageable. Real-time tracking systems may enhance operation efficiency by imparting real-time label process feedback. Instant data on labelling accuracy allows manufacturers to identify bottlenecks, system malfunctions, or operator errors and take appropriate measures immediately. It cuts production delay risk and increases overall workflow efficiency.

3.3 Integration of Data Analytics for Labeling Optimization

Labelling processes can be optimized, and risks of errors are reduced through data analytics. Historical production can be tapped to uncover signals that might reveal problems in labelling. For example, if a data analysis shows that some shifts or operators correlate with a higher error rate labelling, one may need more training or adjustments of workflows. Advanced analytics tools can also predict potential errors before they occur, thus allowing manufacturers to take preventive measures. Machine learning algorithms can be used to build predictive models to analyze production data and determine the probability that a particular pair of production data (such as operator behavior, equipment performance, and environmental conditions) will likely be mislabeled. The models can give manufacturers a heads-up for likely label errors so they can proactively avoid errors. Predictive models could, for instance, alert manufacturers to anomalous trends like an intensifying rate of mislabeling at certain points in the production line because it might reflect issues with the labelling hardware or lack of attendance of operators.

Using data analytics to automate the labelling process means that manufacturers can continuously increase and improve their operations as they scale up by removing it from the cGMP production of batches. The data analysis could be used to make reasonable decisions regarding process improvements, equipment upgrades, and personnel management so that labelling accuracy remains at the highest possible level. Data-driven decision-making also means interventions targeted at specific issues instead of broad reactive measures that may not work as well to prevent mislabeling. Data analytics can also keep compliance with industry standards and regulations by monitoring compliance in real-time and reporting on labelling accuracy (Parimi, 2018). Manufacturers can also use data analytics to produce in-depth reports on labelling performances, tracking progress over time, ensuring the process conforms to regulatory requirements, minimizing non-compliance risk and keeping manufacturers as constant and consistent as possible in producing high quality with high customer expectations.

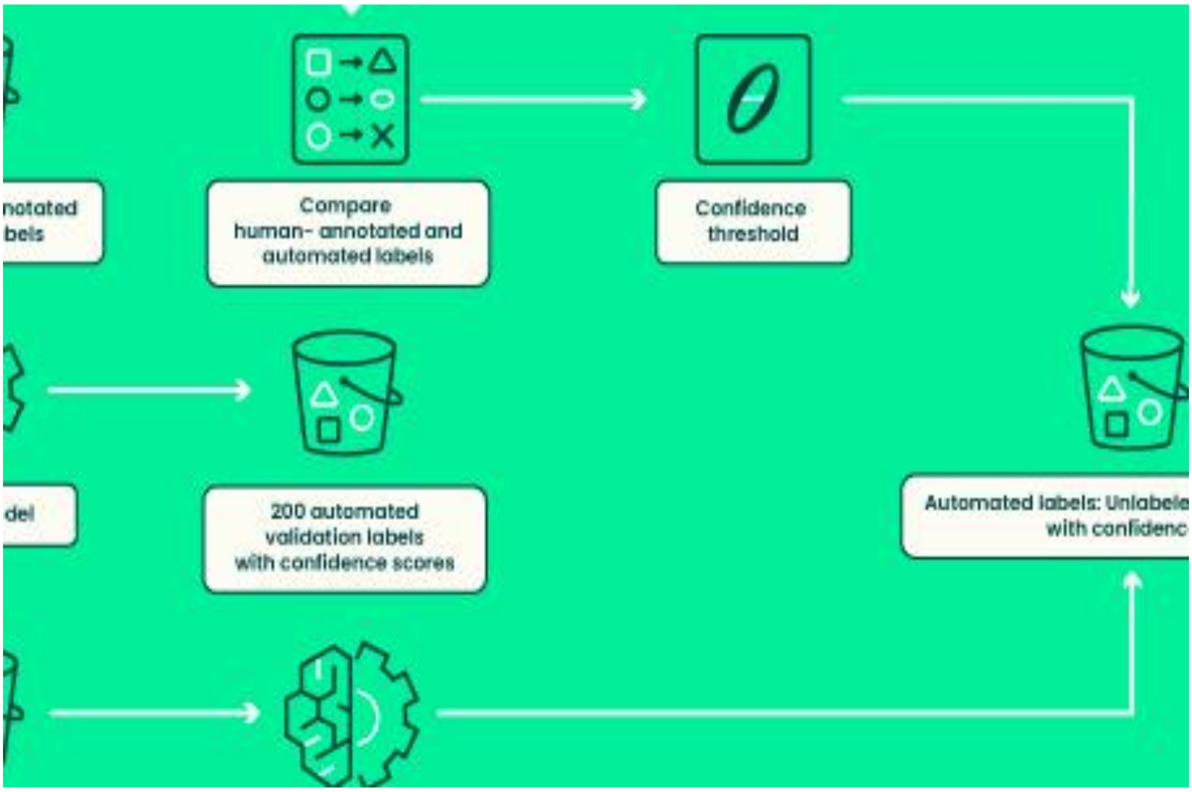

Figure 3: Effective Data Labeling Strategies for Machine Learning

In the complex and fast-moving world of manufacturing today, being able to mitigate mislabeling, technology plays an indispensable role in easing the pain. Real-time tracking devices, such as the IoT RFID and automation, are all crucial technologies that make labelling processes accurate, efficient and reliable. Manufacturing gains the opportunity to significantly reduce the likelihood of mislabeling their products, ensure traceability at all product life cycle stages, increase productivity, adhere to industry standards, and so on. Adopting these technological solutions enables manufacturers to build more robust, resilient, and lean production systems that reduce the risks of mislabeling, and the final products in the organization are of higher quality and help provide better customer satisfaction.

4. Strategic Supplier Management and Labeling Standards

Effective strategic supplier management is necessary for labelling standards to be maintained across the first assembly line. Disrupting the whole supply chain can lead to a mislabeled product and production delays, safety risks, and financial loss. To mitigate such risks, manufacturers have developed proactive strategies that include clear communication, supplier audits and collaborative improvement. Manufacturers can decrease errors, boost efficiency, and comply with regulations by systematically managing supplier relationships and putting in strong labelling standards.

4.1 Defining Supplier Expectations and Labeling Guidelines

If clear expectations are not set early on, suppliers cannot meet the labelling standards in the same reliable way. Manufacturers must inform the suppliers of the labelling requirements and also ensure that suppliers fully understand the importance of the standards in continued product quality and traceability. In supplier contracts, supplier labels should be labelled with explicit guidelines defining the type of labels to use, the level of accuracy of the labelling data, and how to perform traceability and tracking. The labels should be in the format, size and placement of the labels on products or packaging. To ensure labels are readable and scannable by automated systems, there should be specifications for such things as barcodes, QR codes, and other unique identifiers (Uzun & Bilgin, 2016). Manufacturers need to specify the material used to make the labels to ensure that whatever is subject to various environmental factors, such as a change in temperature, humidity, or exposure to chemicals, leading to some labels fading and peeling, stays intact. In addition to the technical specifications, manufacturers should define the operational standards for correct label application. The level to which procedures are defined by which to label each component at various stages of production and by which those labels are checked to make sure they are correct when applied must be defined. It clears the channels of labeling expectations, keeps both sides in sync on goal, and helps avoid miscommunication errors.

4.2 Supplier Audits and Labeling Compliance Checks

Audits and compliance checks within supplier management strategy should be part of the regular schedule to avoid occasionally coming into labeling standards. These audits are a very important step toward detecting potential problems that could prevent a product from affecting its production schedule or quality. In order to ensure that the labels are installed correctly, suppliers should periodically test labels to ensure the processes performed are accurate. These audits involve different aspects, such as checking whether the labels generated are enough, whether these materials are correct, and whether they follow the manufacturer's labeling guidelines. Manufacturers should also consider compatibility with other system operations in inventory management, product traceability, and logistics while subjecting these audits. If the supplier uses barcode labels, they need to ensure that the manufacturer's automated system can be read via the barcodes on the supplier's labels to avoid tampering with traceability while the products are in the supply chain.

Figure 4: Labeling and Packaging Guidelines

The guidelines should be set out, and following these should be a labeled audit that would identify nonconformities or deviations from the guidelines. The audits for these products should be based on a random sampling of the labeling process. The supplier should be required to retrain their staff or change their labeling handling processes to meet those required standards. Spot checks must also be an important component of supplier auditing processes. Spot checks differ from formal audits in that they are unannounced visits to suppliers' facilities where real-time labelling processes are observed and current compliance is assessed. Spot checks give the manufacturer a better view of everyday operations and can spot problems not seen during scheduled audits. Formal audits are combined with regular spot checks as they help regular manufacturers maintain a uniform quality control framework to minimize the chance of mislabeling errors and the action needed to correct issues promptly.

4.3 Collaborative Improvement with Suppliers

Continuity improvement in labelling practices depends on building a strong and collaborative relationship with suppliers. Manufacturers should work as partners with suppliers to collaborate in responding to errors. Collaborative improvement efforts result in more effective solutions that help both parties and contribute to long-term operational success. Sharing data between manufacturers and suppliers is one of the key elements of collaborative improvement. It is powerful because it makes it possible to identify trends and causes of mislabeling and develop solutions, and the decisions made are data-driven. By sharing this data, manufacturers can also communicate to suppliers the performance they would like to see from suppliers to improve. Suppose a specific type of label consistently fails to meet quality standards. Manufacturers can look for more resilient and useful ways of changing label materials or printing processes.

It should also urge manufacturers to get suppliers involved in the labeling process to make them more accurate and efficient. However, good suppliers are also willing and able to provide input into how labeling can be more conveniently incorporated into the supply chain (Tien et al., 2019). This involves the suppliers in problem-solving to get fresh perspectives and new ideas for reducing errors, speeding up the labeling process, and improving product quality. Other important aspects of collaborative improvement are included in training programs. Manufacturers should work with suppliers to organize joint training on what constitutes labeling best practices, what to do with new technologies, and their regulatory obligations. One of these programs will ensure that both parties are up to date with the most recent advances in labelling standards and thus can better confront emerging problems.

Manufacturers should also have a feedback loop with suppliers to keep checking the effectiveness of labelling processes. Regular feedback meetings between manufacturers and suppliers can set a labelling system in motion to evolve to meet new requirements and industry standards. Consistent labelling through effective strategic supplier management is crucial to avoid the risk of mislabeling and its associated costs. Supplier audits ensure that the expectations for labelling are made clear, a collaboration between the two parties helps ensure quality control is good, and continuous improvement is encouraged. These are efforts made by manufacturers to ensure constant meeting of standards for labelling, thus ensuring product traceability, reducing errors, and ultimately improving the efficiency of the supply chain.

5. Organizational Culture and Continuous Improvement

5.1 Fostering a Quality-First Culture

In the manufacturing processes, an organization can commit to a quality-first culture to reduce mislabeling errors. Mislabeling is less likely to occur when quality is a priority at all levels, from top management to shop floor operators. A strong leadership commitment must be passed down in all departments to build a quality organizational culture (Warrick, 2017). Management needs to set clear expectations for quality, provide the necessary resources, and create an environment where quality is not an end in itself but a constant process. The process of bringing this change to a manufacturing environment starts with extensive training on the value of proper labelling, clear communication of standards, and continual support at all company levels. Quality must be considered an important responsibility apart from a function of a specific department, and employees must be encouraged to take it in that sense. Suppose operators on the production line should be empowered to report labelling issues as soon as possible without fear of retribution. By taking this proactive approach, any possible mislabeling issues are caught in the bud and do not grow to be larger issues only. Mandating quality metrics to evaluate the company's performance encourages the veracity of labels (Song et al., 2017). Defect rates, labelling accuracy, and error rate frequency can be the metrics. This is part of an organizational campaign towards cultural change, which can indirectly encourage people's recognition of individuals or teams that preserve high-quality standards daily, being recognized by peers, and pushing others to follow. The final objective is for quality to be a cooperation between all employees and everyone involved in preventing errors like mislabeling.

5.2 Lean Manufacturing and Its Impact on Labeling Accuracy

Adopting Lean Manufacturing principles can also directly impact labelling accuracy since doing this can increase the efficiency of workflows and minimize or eliminate possible error-creating elements. The key focus of lean principles is reducing waste, including minimizing errors and inefficiencies and maximizing value in production processes. Lean techniques applied to labelling processes will allow organizations to create a better flow of materials, minimize the occurrence of mislabeling and provide a more efficient production atmosphere. Eliminating the nonvalue-added or the nonvalue-added activities known as waste is a key component of Lean Manufacturing. In the labelling context, waste can take many forms, such as redundant labelling, excessive manual handling, or unclear labelling instructions mislabeling results from all those inefficiencies, confusion, miscommunication, and mislabeling. Reduction of the number of times an item is handled during labelling by streamlining processes such as automating as much as practicable, when possible, will significantly reduce the risk of errors.

A practical Lean approach using standardized work procedures can improve labelling accuracy. Standardized work specifies all the standardized tasks to be performed in the labelling process in a standardized way. This makes committing an error while doing these procedures impossible because they would always identically do this. Checklists or visual guides to labels can be provided to operators to ensure that the labels they apply are accurate. This helps optimize performance consistency in task labelling by minimizing how the tasks performed vary. Apart from the concept of standardized work, Lean Manufacturing also uses the use of just-in-time (JIT) practices, and these can also benefit the processes of labelling. The goal of JIT systems is to avoid inventory management errors by having the right components available at the right time and in the appropriate quantities (Mankazana & Mukwakungu, 2018). This also decreases the possibility of misusing or labelling the part. Implementing Lean Manufacturing leads to minimum labelling errors and improves the production flow through improved coordination and better timing of material deliveries.

Table 1: Summary of Key Strategies for Enhancing Labeling Accuracy in Manufacturing

Concept	Key Points	Impact on Labeling
Fostering a Quality-First Culture	Leadership commitment, clear expectations, employee empowerment, quality metrics	Creates a culture where quality is prioritized at all levels, reducing mislabeling through proactive actions and feedback.
Lean Manufacturing	Waste reduction, workflow efficiency, JIT, standardized work procedures	Reduces mislabeling by streamlining processes, minimizing errors, and ensuring timely availability of components.
Continuous Improvement through Feedback Loops	Kaizen, Six Sigma, feedback collection, data analysis, flexible adaptation to change	Enhances labeling accuracy by using ongoing feedback and data to identify and correct errors, improving

		process reliability.

5.3 Continuous Improvement through Feedback Loops

Continuous improvement is a critical component of modern manufacturing practice, and labelling implementation drastically reduces the probability of label labelling. The feedback loops within the organization make it possible to collect, analyze, and apply data on an ongoing basis to improve processes and initiate continuous improvement. In the label context, feedback loops imply periodic monitoring of the labels' accuracy and errors, which lead to the mitigation of the latter. Kaizen is a well-established approach, and it is based on small, incremental, continuous improvement over time. Kaizen motivates all employees, from the shop floor to management, to assist in problem-solving and process improvement problem-solving. Applying Kaizen in the case of labelling can be used to determine which areas errors generally happen, identify the root causes, and take corrective actions. An example of when a Kaizen event would be appropriate is if the label printer is found to be the cause of an error, such as a poorly calibrated or poorly maintained label printer. The Kaizen event would lead to better maintenance practices and calibration schedules, reducing the risk of future mislabeling.

The labelling process can be applied to the Six Sigma methodology to reduce labels and eliminate sources of variation that increase defects. Using statistical tools, the Six Sigma method measures performance, locates defects, and improves processes. Labelling could involve setting strict thresholds for accuracy and continuously looking at performance results against those thresholds. Manufacturers can use the data analysis to understand the common causes of mislabeling, such as operator errors, equipment malfunctions or misinterpretation of label requirements and take corrective actions. One of the main ingredients of continuous improvement is setting up a culture in which feedback is collected in process and to improve those processes. At all levels of the organization, the labelling performance, such as error rates or cycle times, should be reviewed regularly. If issues are seen, it is very important to make fast changes to avoid the recurrence of those issues. For example, operator feedback reveals problems in reading labels because the print and font are poor. Such feedback allows producers to adapt and adjust to improve labelling and reduce errors.

Continuous improvement requires the organization to be adaptable and flexible to change in the manufacturing environment. The aim continues to continuously evaluate the effect of new technologies or processes on labelling accuracy and efficiency. The proactive practice of ongoing improvement, whether through adopting new labelling technologies, process automation, or improving the training program, gives rise to the fact that such mislabeling issues are handled (Charlebois et al., 2021). In order to minimize the errors in manufacturing caused by mislabeling, it is fundamental to build a quality-first culture, thus applying the principles of Lean Manufacturing and setting up continuous improvement processes based upon feedback loops. These strategies increase the accuracy and the credits of labelling practices and help benefit the organization by reducing waste, product quality, and production flow. With a promise to positive continuous improvement, manufacturers can guarantee labelling accuracy as a top priority for more effective and efficient production.

6. Mislabeling SCAR at an Automotive Company

6.1 Problem Statement

An automotive company was interned, and some mislabeling issues were identified that hindered the accuracy of parts labelling in several suppliers. Suppliers A, B, and C faced problems with labelling the core component and the risk of misidentification of the components. They could have consequently misused the components on assembly. The error of such dimensions can result in compromised product safety and quality and severe operational disruption. Mislabeling components in the automotive field is a formidable challenge, and this is especially true for safety-critical parts, as any small differences may cause catastrophic failures not only to the safety-critical parts but also to the vehicle (Richter, 2017). Given that the safety and integrity of the products, as well as the regulations and the customer's requirements, depend on the quality of the products, addressing mislabeling was seen as one of the top priorities.

6.2 Root Cause Analysis

By taking a data-driven approach to analyzing the mislabeling incidents, comprehensive root-cause analysis was undertaken to determine the underlying pressures causing them. Other contributing factors to the problem were identified by reviewing production logs, scrap rates, and operator error reports. The first problem was an overproduction of labels. An analysis of the number of labels printed by the pressman revealed that he printed too many labels, which confused the shop floor and misplaced labels (Sampath, 2018). As there was an overabundance of labels, workers had a greater tendency to place incorrect labels because they were ambiguous, especially where there were similar-looking parts or materials. The problem only worsened due to the human tendency to use available labels, which were often wrong.

The scanning process was at the heart of the second issue. The FIP (First in Position) label was scanned multiple times to complete a pallet for every operator, unintentionally resulting in repeated errors. This repetitive scanning led to discrepancies in the label application process. The system could not detect multiple scans on a single item, eventually resulting in mislabeling parts. These parts caused downstream problems in sorting and assembly as they moved through the production line without being labelled correctly until even later stages of the process. There was also a great misinterpretation of the traceability requirements among the operators. A detailed review of operator training records revealed that many operators lacked knowledge about their company's traceability standards. This label confusion arose from the training gap, party, and ally due to parts needing special handling or identification protocols. As a result, different labelling practices made the mislabeling problem even more serious due to confusing traceability protocols.

Figure 5: Benefits of Supplier Corrective Action Request

6.3 Corrective and Preventive Actions

The company took various corrective and preventive actions to minimize the future risk of mislabeling incidents. The company also used data-driven insights based on these weak areas found through analysis. The label printing process was adjusted after one of the first few steps. The company implemented a policy in which the labels are printed only as needed, based on a specific work order requirement. Based on the data from production logs, one of the main causes of mislabeling was excessive labelling, which is how they solved this problem. Mule reduced a worker's risk of being stuffed with labels by limiting the production of labels. This change also facilitated operations and reduced opportunities for wrong components to be tagged with unnecessary labels. To deal with the scanning errors, the company developed a dual-scanning process. The operators were forced to scan both Supplier A and company labels before starting the palletizing process (Kunwar Jr, 2019). Adding this verification layer effectively ensured that each label was correct and belonged to the specific component. The dual scanning process was implemented based on production logs, which indicated that this simple procedure would dramatically decrease the number of errors in single-label scanning.

The training was instrumental in doing the job of labelling better. A specific training program was implemented to ensure operators grasped the importance of proper labelling and how to track every part of a component. Much of the mislabeling resulted from operator error, which operator error data suggested was due to poor or untrained staff. The company hoped that adding more comprehensive training would address this confusion and that the better-communicated importance of using standardized labelling protocols would increase the labelling process's overall accuracy. The company changed to include QR codes on the FIP labels. Traceability audits showed that the use of QR codes reduces the frequency of mislabeling incidents and increases scanning accuracy. The QR code served as an additional validation level and provided quicker and more reliable data capture through the production line.

The company also initiated immediate containment measures in response to ongoing fact issues regarding labelling. These measures were devised to remedy the immediate damage caused by mislabeling and deter any further disruptions of the production process. A principal containment measure was to relabel boxes with the company's part number (PN) of the box's contents. Inventory audits confirmed that up to 90% of mislabeling errors were reduced with relabeling. This caused the company to avoid confusion and misapplication of labels by ensuring that the labels on the boxes reflected accurate contents (Hartono & Azman, 2019). Since this quick fix reduced the impact of the mislabeling incidents, it was effective until more long-term corrective actions could be implemented. The company also took another containment measure when it compared the FIP label with its label before the parts were sent for assembly. When labels were matched before they were assembled, errors decreased by 85%. Since this simple measure, only correctly labelled components were used for final assembly, thus preventing the introduction of defective parts into finished products.

6.4 Containment Measures

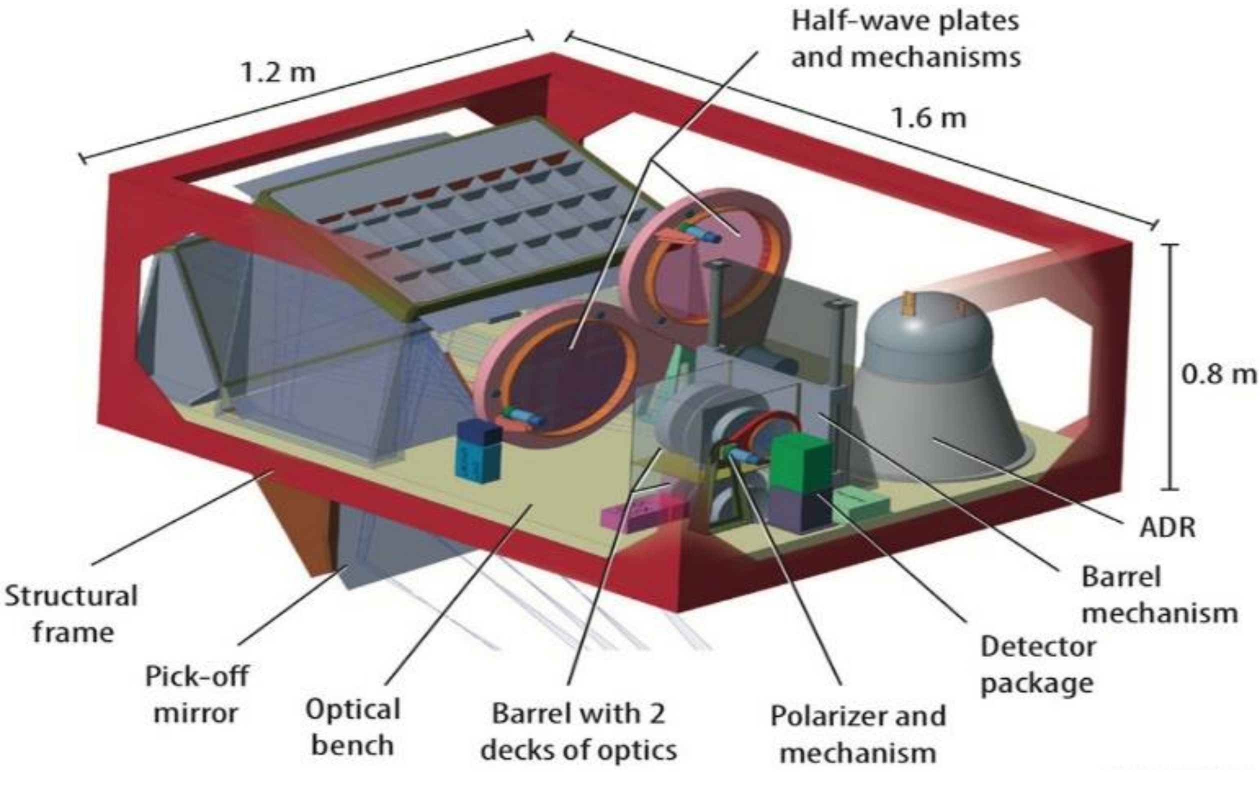

Figure 6: An Overview of the FIP mechanical structure and components

They worked so that these containment measures successfully minimized the impact of mislabeling errors as the company dealt with more comprehensive measures. Introducing these measures ensured that the company could proceed with its production deadlines without decreasing the quality or safety of these products.

Through rolling out corrective and preventive actions rooted in a data-driven approach, the company was able to fix the root causes of mislabeling in its production process. The company chose to focus on areas like label printing, scanning accuracy, and operator training to improve its labelling practice and significantly reduce the occurrence of labelling errors (Oldland et al., 2015). Containment measures used were relabeling and label matching, which served immediate, if not perfect, relief against the impact of mislabeling while better, more permanent therapies were being developed. This enabled the company to improve the product, operational efficiencies, and safety so that no such issue would repeat.

7. Post-Production Monitoring and Labeling Traceability

Post-production monitoring and labeling traceability are components of modern manufacturing systems. These processes guarantee quality labeling, traceability support, and correct processes that do not compromise product integrity or safety. As everyone drives towards standardization regarding transparency, accuracy, and regulatory compliance, advanced technologies are used to monitor and validate labeling data throughout the lifecycle. Post-production monitoring and labeling traceability systems effectively prevent mistakes, manage costs, and ensure consumer safety and long-term operational efficiency.

7.1 Real-Time Monitoring of Label Accuracy

In a modern manufacturing environment, accurate application of labels is essential for product traceability and meeting regulatory standards and product quality. Monitoring systems that track the accuracy of labels in production and package lines have to be real-time (Kumar, 2019; Dodero et al., 2021). These systems use sensors, cameras, and barcode readers to continuously scan, verify labels, provide real-time feedback to the operators, and corroborate any discrepancies on a real-time basis. Integration with existing production equipment often allows manufacturers to monitor labeling errors during production rather than later in quality control or, worse after products hit the market. Doing this proactively reduces the risk of shipping mislabeled or missing product information, batch numbers, expiration dates, and regulatory compliance marks.

Manufacturers can automatically check each label's alignment, placement, and content by using vision systems, barcode scanners, and RFID (Radio Frequency Identification) readers. The first group comprises high accuracy, high-speed technologies (implies a system itself), which apply the correct labels to the correct products in real-time. For example, artificial vision systems enabled with artificial intelligence (AI) can identify the most common label errors, such as wrong printing, misalignment, and incorrect data. These systems, consequently, let manufacturers handle labeling problems before they become serious difficulties. Real-time monitoring is more than error detection. These systems generate data that can be used to identify recurring problems in the labeling process and the root cause of the errors. This allows manufacturers to correct any issues, such as retraining the operators, adjusting machine settings, or redefining the labeling procedures to ensure sustainable future improvements.

7.2 The Role of Blockchain in Ensuring Labeling Transparency

Blockchain technology is gaining strength in providing labeling transparency and traceability in manufacturing. In simple words, a blockchain is a decentralized digital ledger that records transactions securely, immutably, and transparently. When applied to labeling traceability, blockchain creates a transparent record of where traceable raw product materials are sourced, the labeling by which they were conveyed to the product, and where the final product left the production line (Figorilli et al., 2018). Recorded labeling information on a blockchain can verify and ensure a favorable and incontrovertible record of a product's labeling history. This record contains necessary data such as component origin, manufacture dates, labeling specifications, and regulatory compliance. Each piece of information added to the blockchain becomes immutable, meaning that once data has entered the blockchain, it can never be changed or deleted to ensure that data is always trustworthy.

Blockchain would also help improve the supply chain's overall visibility. This data is easily available to stakeholders, including manufacturers, suppliers, regulatory bodies, and consumers, in real-time so that everyone knows the same accurate and up-to-date information. One example is that blockchain tech can help identify what caused an unfortunate mistake where logistics might come into play. For example, an error was made with a label printed by a supplier or a manufacturing defect. With this, they can easily detect and resolve the discrepancy in labeling, thereby minimizing its effect on the entire production activity. Blockchain can also guarantee compliance with industry regulations, like those imposed by the FDA in the food and pharmaceutical industry (Charles et al., 2019). Blockchain lets regulatory bodies centralize compliance record keeping, batch tracking, expiration dates, and ingredient disclosure in a secure and easily accessible place as they increasingly require more detailed labeling information. The tracing of product management is one application of blockchain where the product can be tracked from when it is manufactured to when it is sold off.

Figure 7: The Role of Blockchain in Ensuring Transparency in Labeling

7.3 Post-Production Audits and Labeling Quality Control

Once the product gets out of the production line, it needs to be audited by something. Ensuring that the labels are still up to the required standards is necessary. The most common quality assurance system consists of several components, including post-production audits, which assure that the labeling works correctly and that there are no problems during this process before the product reaches customers or retailers. Upon completion of production, one reviews the end products to check if the labels are placed correctly, are readable, and comply with regulatory standards. These audits may include random sampling of finished goods and automated systems checking that the finished goods are labeled accurately. The function of auditors is to check for several factors, including the correct font sizes, color accuracy, the functionality of barcodes, and whether they align with industry regulations. The combination of regular audits as a fail-safe mechanism and real-time monitoring should catch most of the errors missed in the first place. For instances, an automated system can alert a human auditor upon a discrepancy in the labeling data, such as an incorrect barcode or incomplete data.

Centinela argues that these audits make sense, as manufacturers want to track down any labeling errors before distributing the product to prevent consumer complaints, legal disputes, and expensive recalls. Manufacturers can use auditing practices to discover trends or patterns of mistakes with labeling accuracy. The analysis of audit data aims to point out systemic problems in the labeling process by identifying equipment malfunctions, training gaps for the operators, and design faults in the labeling materials. Once they get this information, they can improve your process, improve labeling workflows, or perform better quality checks to prevent such errors. Such post-production audits can comply with industry regulations and standards. When errors in labeling can lead to very serious implications for law and safety, these industries are highly regulated, such as pharmaceuticals, automotive, or food production. Before making products available on the market, routine audits are conducted to confirm that the products comply with the labeling regulations. By going through this process, companies can put little or no risks of regulatory fines, product recalls, and potential health hazards for their consumers.

In the modern manufacturing world, several important tools are utilized to ensure that labeling is accurate, transparent, and compliant, such as post-production monitoring, blockchain integration, and post-production audits. Manufacturers can install real-time monitoring systems that identify errors before they occur, avoid problems downstream, and increase overall operational effectiveness. The labeling data can be tracked through a commendable and secure blockchain technology framework that keeps traceability and regulatory compliance. Regular post-production audits at the end ensure that the products meet the required labeling standards. This helps manufacturers control the quality and avoid legal or minor safety issues (Montgomery, 2020). These practices make the whole manufacturing process more reliable, efficient, and transparent, which benefits the consumer and manufacturer alike.

8. Legal and Regulatory Implications of Mislabeling

Mislabeling is an operating issue of a firm, as well as its legal and regulatory problems. By breaking national and international standards and the law and posing a risk to product safety, incorrect labeling may have serious consequences. The above implications are important because product quality depends heavily on automotive, pharmaceutical, and food safety (Lawrence & Kopcha, 2017). The second section will analyze legal and regulatory consequences, compliance with international standards, risks, liabilities associated with mislabeling, and the equivalents of mislabeling on the product recall procedures.

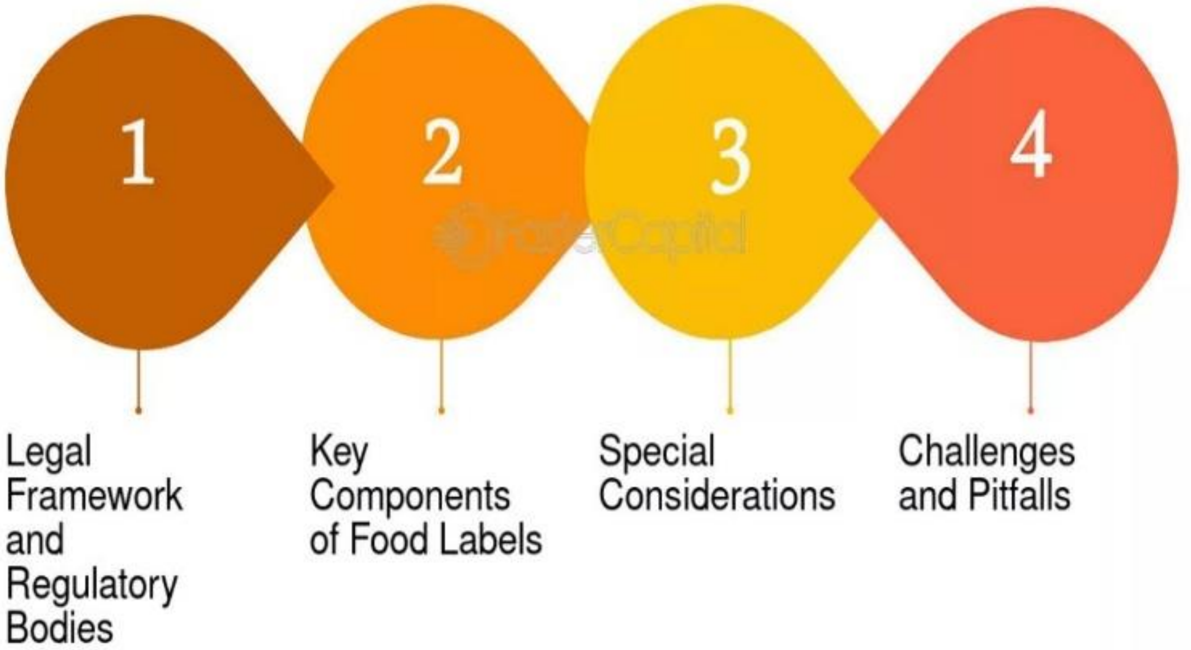

Figure 8: Importance of Product Labeling

8.1 Compliance with International Standards

Mislabeling is one of the most important legal implications of mislabeling in manufacturing because it does not comply with international standards such as ISO 9001: 2015. ISO 9001:2015 is a widely recognized standard of system quality management, which should promote the manufacture of products via a consistent system control of quality. Accurate labeling is imperative to these standards and keeping product quality consistent. They can bet that for the manufacturers, failing to comply with the ISO 9001:2015 standards because of mislabeling can result in substantial legal injuries. Because compliance with ISO standards is regulated by regulatory bodies across different countries, non-compliance could lead to (and be followed by) fines, suspension of the certification, and the loss of business relationships with suppliers and customers. The automotive and healthcare industries require certification of products for distribution and sale, and mislabeling can lead to the withdrawal of certification. Mislabeling could result in customers or competitors suing them, increasing legitimate risks even more (Paben, 2015). If labeling practices comply with such international standards, complete audits and frequent checks guarantee the accuracy of labeling. Manufacturers must also launch robust training programs for people involved in labeling to learn the importance of metabolism in quality administration standards. In this regard, computerized labeling systems with digital tracking programs can solve the problem as intricately as possible. They will not in any way introduce errors experienced by the human factor or follow the ISO 9001:2015 procedures.

8.2 Legal Risks and Liabilities

Incorrect labeling and violating manufacturing standards are illegal and require very formidable legal risks and liabilities of the supply chain, especially in the automotive, food, and pharmaceutical industries. The establishment of false labels in these sectors will lead to the distribution of unsafe or unapproved products that are dangerous to public health and safety. For instance, in the pharmaceutical industry, mislabeling may lead patients to get the wrong treatment of drugs and have bad impacts on the patient’s health (Lippi et al., 2017). In the automotive sector, faulty components may be responsible for injuries, fatalities, or accidents like an unfit airbag or missing brakes. These consumers, regulatory bodies, and other stakeholders would sue such manufacturers for negligence, product liability, and breach of contract. In these contexts, lawsuits can result in hefty financial settlements, damage to the company's reputation, and even criminal charges. There are two types of regulatory agencies for product safety: the FDA and the NHTSA. Such agencies have strict labeling requirements, and failing to meet these requirements can lead to regulatory actions such as recalls, fines, and litigation. If there is a legal action, manufacturers must prove they used all reasonable measures to correct their product labeling. Some of that includes evidence of proper training, quality control processes, and the corrective action taken when they have mislabeled identified incidents. Not showing such measures could put the Manufacturer at risk of extremely high legal exposure.

8.3 Impact on Product Recall Procedures

Product recalls are mostly a byproduct of mislabeling, especially for industries emphasizing product safety. The recall is a legal mechanism through which manufacturers must recall unsafe or defective products from the market, especially in case of mislabeling, making way for safety hazards. For example, in the automotive industry, Manufacturer recalls of whole vehicle models due to mislabeled components like airbags, brakes, or tires can result in high financial and reputation costs to manufacturers. Mislabeling can also cause a product recall, which, in turn, can create a cascade of legal and financial downfall for the Manufacturer (Lindberg & Sohlin, 2021). In recalls, there are public announcements, logistic or technical challenges to collect the involved products, and the expenses of reducing or replacing the affected products. Manufacturers must inform relevant regulatory bodies, such as the NHTSA in America or the European Commission in the EU, of the recall. Failing to follow recall procedures is a way to pay the court and suffer from lawsuits and more regulatory scrutiny.

Product recalls can also have long-term implications on the Manufacturer's reputation. Manufacturers provide high transparency and accountability in industries such as safety, where safety is a top priority, which consumers expect by default. Mislabeling can result in a recall. Consumers will lose trust in the manufacturer’s products, leading to lower sales and market shares and a subsequent bad reputation for the manufacturer’s goods. The company might lose industry certifications or even secure contracts from key stakeholders if it fails to respond to customer requests, making its financial and operational position uncertain. Manufacturers need a good labeling and traceability system to mitigate the risk of product recalls due to mislabeling. They keep tabs on what type of a product and where it is being shipped on the supply chain and that products are properly labeled at every stage (Bottani et al., 2017). Manufacturers should take up the prevention of mislabeling from resulting in a recall on an intrinsic basis through their own internal audits and corrective action. Automated labeling systems and real-time tracking solutions, such as RFID, greatly reduce the risk of mislabeling errors with data-driven solutions.

The manufacturing process requires legal and regulatory compliance, and serious challenges arise from how using any mislabeling in manufacturing can carry far potential financial, operational, and reputational impacts on the manufacturing firm. Everything depends on it, so the one thing to be done is to comply with international standards such as ISO 9001:2015 to escape from legal risks and the case of operations. Furthermore, manufacturers who label wrong products are at high risk of being sued and penalized if government regulations are a key concern in their industry (Kwok, 2017). This may also involve recalling the mislabeled products, which would damage another part of the company's bottom line and its reputation in the marketplace. This means that if manufacturers fail to practice accurate labeling practices, auto systems, and strict quality control measures to convey themselves, they do not go into legal and regulatory issues.

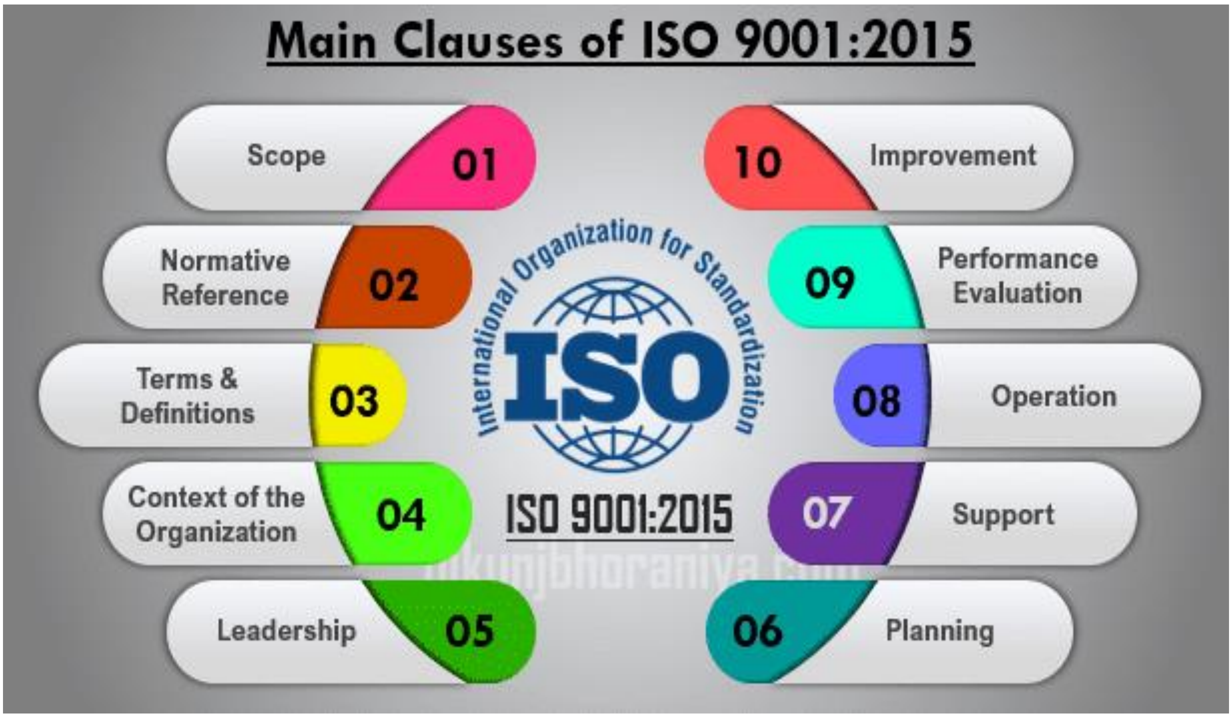

Figure 9: An Overview of ISO 9001:2015 Quality Management System Main Clauses

9. Recommendations for Industry-Wide Improvement

9.1 Implementing Advanced Labeling Technologies

Advanced labeling technologies will help reduce incidents of mislabeling and establish greater traceability along the manufacturing process. QR codes and RFID tags are the best ways to improve the accuracy of labels and identify components, materials, and products. These technologies make it possible to trace a product from raw material production to the factory of final assembly in real-time. Product traceability can be improved with a cost-effective and versatile QR code solution (Urbano et al., 2020). They have storage capabilities for manufacturing dates, batch numbers, and material specifications. These codes are scanned and immediately take operators and systems to the correct information, thus ensuring the proper part is utilized in the production process. RFID tags have even more powerful tracking capabilities. These tags can check their status for continuous monitoring and be read at different supply chain stages without a direct line of sight. By doing so, higher reliability in tracking items will be achieved compared to traditional barcodes of manual systems.

These technologies can only be implemented using a data-driven approach. Manufacturers must assess the specific needs of their production environment and the supply chain before they choose and deploy QR codes or RFID tags. RFID is particularly beneficial to manufacturers with a highly dynamic inventory system, for example, making real-time, automated data capture possible. Data analytics can evaluate how these technologies work and whether the manufacturers need changes to optimize the technology's performance (Popovič et al., 2018). These advanced technologies can also be integrated into an automated labeling system to facilitate the process. Automation minimizes human error, increases throughput, and provides ultimate control concerning predetermined standards of labeling each product. If the product has certain characteristics and batch documentation, these systems can be programmed to apply and validate labels automatically.

9.2 Training and Education

An oft-overlooked pointer for improving labeling accuracy in numerous domains is the basic requirement to channel extra effort into training operators, supply chain managers, and other people involved in the labeling process. Such a training program also helps them realize product safety, quality, regulatory compliance with the industry, and a proper program to mitigate the risk of mislabeled products. Training in the industry's labeling requirements must begin with a good knowledge of the industry labeling, including ISO 9001 and other equivalent quality management Systems. They need to be sensitized to the consequences of mislabeling, ranging from production delays to unsafe products, putting lives at risk, and product recalls. Such a labeling culture will help establish and create an accountability culture where labeling accuracy is a constant, walking through every node of the organization.

The training program's effectiveness can also be improved by incorporating data-driven insights. For example, data from these error reports can empower manufacturers to tailor training sessions to the most common sources of mislabeling that error reports identify. Instead of training for generic skills that apply across the board, those in charge of training programs can focus on the specific challenges that operators face, such as the misunderstanding on how to interpret labeling instructions or confusion on traceability requirements. Employees should be trained once and trained periodically. Instead of a one-time training, as the title suggests, they need periodic training and refresher training. There are labeled operators in simulated environments, which can be applied with labels to practice categorization and increase confidence and competency. The training should involve digital tools with label management embedded into the production system such that workers confirm label accuracy in real-time through a label validation feature(s) in an integrated software platform (Bian et al., 2021).

9.3 Continuous Improvement Programs

Continuous improvement programs work because they continuously reduce mislabeling by making a system of processes more efficient and eliminating waste. These programs are also known as Lean Manufacturing and Six Sigma (Kavčič, & Gošnik, 2016). They have recorded programs that make decisions based on data and identify and remove inefficiencies in the production system. With systematic production data analysis, the manufacturer can reveal the root causes of mislabeling and take corrective action to prevent recurrence. Because they emphasize eliminating waste and simplifying production, Lean Manufacturing principles effectively cut labeling errors. The manufacturer can implement Lean initiatives to make the labeling process more efficient and error-free by identifying unnecessary manual interventions, redundant checks, or excessive motion, which are considered non-value-adding activities in the labeling process. For example, using the Lean methodology's 5S (Sort, Set in Order, Shine, Standardize, Sustain), tools can ensure that labeling stations are organized, tools are ready to use, and processes are standardized, reducing the risk of errors.

Six Sigma attempts to reduce variation by applying statistical methods to eliminate defects in manufacturing processes. In addition to being a Six Sigma DMAIC framework, manufacturers can apply this framework to the labeling process to establish clear metrics for labeling accuracy, track performance, and continually improve labeling processes (Gitlow et al., 2015). Not only does it minimize the occurrence of mislabeling, but it also contributes to improving production efficiency, quality, and customer satisfaction.

Figure 10: DMAIC Methodology

Data-driven decision-making plays a crucial role in both Lean and Six Sigma methodologies. They can also collect data on labeling errors, scrap rates, and rework costs and analyze the data to determine trends and major problems. For example, suppose they see on the data that a specific labeling machine consistently gives an error. Purchasing upgraded equipment or adjusting the current machine may be prudent to improve accuracy. Employee performance data can also assist us in identifying areas where more training is needed. A culture of continuous improvement allows manufacturers to empower their employees to improve and claim accuracy in labeling. Other ways to prevent problems from becoming significant are to have regular Kaizen (continuous improvement) meetings and employee feedback mechanisms to discover and fix misfortunes before they get bad.

9.4 Supplier Collaboration

Any manufacturer must cooperate closely with its suppliers to consistently guarantee that labeling standards are met. Supplier collaboration supports maintaining high-quality labeling practices throughout the entire supply chain so that no mislabeling problem arises at the source. To help avoid real problems, communication channels need to be set up, and audits must be carried out regularly. They define and communicate labeling standards and expectations with suppliers because one of the first things they do with suppliers is to collaborate effectively (Belkadi et al., 2017). Supplier contracts must include specific labeling requirements so everyone is on the same page regarding what will be done. This involves determining the type of labeling technology, what information should be placed on the label, and what reliability standards are needed. Suppliers should be ensured that they understand the importance of accurate labeling and its impacts on product quality and safety to minimize errors.

Supplier audits and compliance checks that are run regularly ensure that labeling standards are being met. Whilst they would expect manufacturers to assess these things, suppliers should assess whether the correct labeling technologies are being used by selecting the appropriate label, applying it correctly on the product, and ensuring that common labeling practices comply with regulatory requirements. Data recovery can make these audits more effective. Historical data related to supplier performance can be analyzed, patterns of label errors can be identified, and the manufacturer can track those suppliers for closer scrutiny or corrective action. Additional characteristics that enable a strong relationship and additional benefits include building cooperative relationships with suppliers, which can lead to shared best practices and mutual improvement. In the case of the example illustration, manufacturers may find synergies with their suppliers to implement more efficient labeling processes or adopt new technologies to help obtain more accurate labeling. Joint problem-solving initiatives can deal with the actual source of the problem, for example, bad quality control or incorrect communication regarding the labeling requirement, thereby ensuring more accurate labeling along the supply chain (Simangunsong et al., 2016). A manufacturer can ensure that production is not affected by mislabeling if the suppliers consistently meet the labeling standards, strengthen traceability, and maintain the integrity of the product.

10. Future Considerations in Addressing Mislabeling in Manufacturing

As the manufacturing industry faces a great challenge in responding to pressure to improve efficiency, reduce costs, and maintain product quality, managing the problem of mislabeling is still an important issue. Manufacturers can now avail themselves of new technological tools that enable new means to improve labeling accuracy and efficiency (Mohamed et al., 2019). They agree with industry goals such as efficiency, sustainability, global standardization, and continuous improvement. The remainder of this section will cover the important points regarding fighting mislabeling in manufacturing in the future.

10.1 The Role of Artificial Intelligence in Labeling Accuracy

Mislabeling problems can also be improved by artificial intelligence in manufacturing processes. It can learn from past mistakes and predict the mistakes in advance, thereby identifying inconsistencies in labeling a problem. The best thing about AI-powered systems is that they can continuously optimize labeling practices by continuously reviewing the data production history to understand what the production data pattern or anomaly means and whether there is a risk of mislabeling. One of AI's most important benefits to manufacturing is the ability to quickly ingest massive amounts of information to enable manufacturing to identify errors quickly (Wan et al., 2020). AI can analyze live production data from automated label applications or visual inspection systems to detect errors in that product with the label. AI contributes to fine-tuning the parameters in real-time, which can decrease human intervention and decrease the possibility of errors in labeling procedures.

From a manufacturing perspective, manufacturers can do this by incorporating AI at the production line level. This will reduce the occurrence of errors caused by mislabeling, which can otherwise occur at the level of human error, and allow for more reliable, consistent, and effective labeling systems. AI can also improve traceability by cross-referencing the label information with other possible production data to confirm that all the components are appropriately identified and can be tracked during the supply chain.

10.2 The Evolution of Smart Labeling Technologies

The third opportunity to tackle mislabeling in manufacturing is the continued evolution of smart labeling technologies. Dynamic and real-time elements of updated status and movement of a product through the supply chain through smart labels, like RFID (Radio Frequency Identification), NFC (Near Field Communication), or QR codes. The smart label can store and transmit a huge amount of data, thus allowing the manufacturer to monitor the condition of the articles and parts more accurately. For example, materials or components may be tracked within production and distribution in real time with RFID tags positioned in the exact location to ensure they are labeled and handled correctly. The technology allows manufacturers or anyone involved in the supply chain to identify mislabeled items while in transit and catch errors before they become quality issues or delay issues. Interactive digital labels that can show up-to-date information to the demand are promising for future labeling in manufacturing. These can also give workers immediate access to important data, such as specifications, traceability codes, or modeling dates. Smart labels ensure that all the labeling data is accurate and readily available, significantly reducing the possibility of mislabeling and increasing overall process visibility.

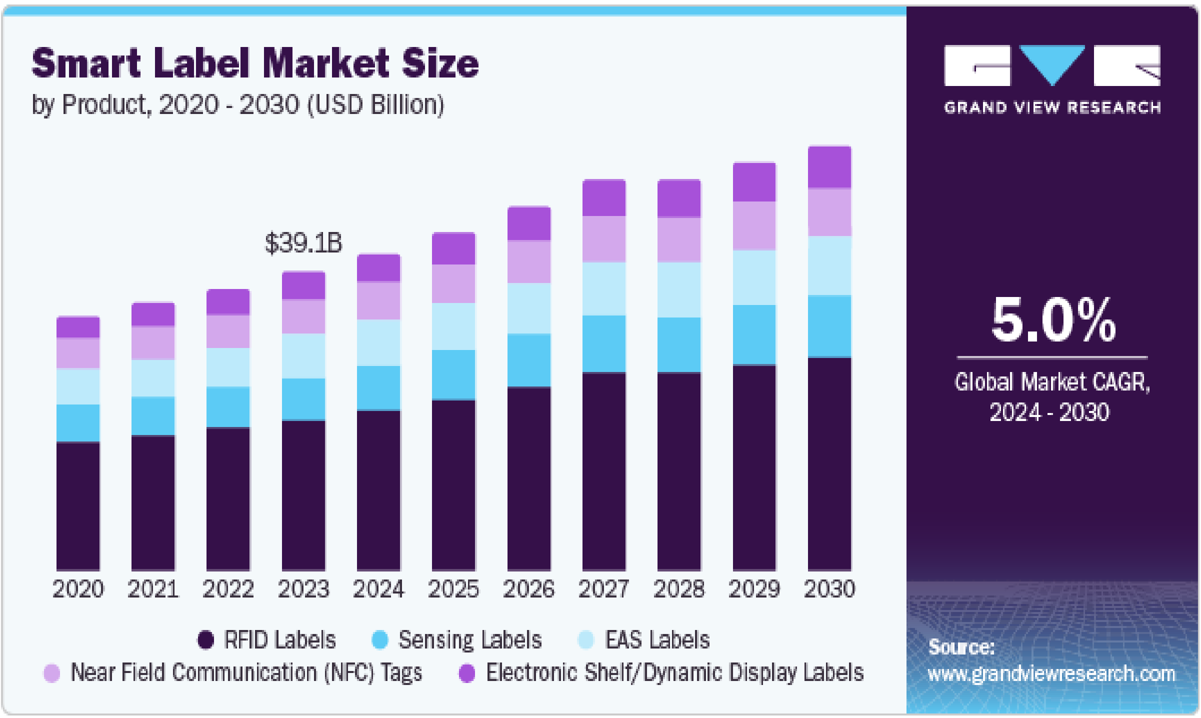

Figure 11: A Future Trends Analysis Report showing the Prediction of Smart Label Market Size and Share

10.3 Integration of Augmented Reality (AR) for Training and Quality Control

AR technologies could be integrated into manufacturing to significantly enhance operator training and real-time quality control processes to reduce labeling errors. AR can give workers immersive, interactive experiences to learn and conform to such labeling procedures and traceability standards. AR can be used for training by simulating labeling tasks, allowing operators to see what they should be labeling, and training them hands-on in a controlled environment. By using AR-powered headsets or mobile devices, workers will receive step-by-step guidance during the labeling process to reduce errors from lack of training or misunderstanding of labeling requirements. Real-time feedback that AR provides can reinforce correct practice as they go and immediately pick out problems (Mourtzis et al., 2020). AR technology can also be used in real-time during any production inspection. The system provides opportunities to scan labels or products with AR glasses or devices and displays whether labels match the required standards. The advantages come from this immediate feedback, which prevents operators from mislabeling by warning them of errors before they become bigger problems. AR's integration into manufacturing processes could save manufacturers time in operations and reduce mistakes in labeling, thus increasing the quality and safety of the product.

10.4 Sustainability and Circular Economy in Labeling Systems

With sustainability being the focus in the manufacturing world, future labeling systems must focus on circular economy principles. Traditional methods of labeling are known to have high environmental impacts through excessive waste in the form of plastic-based material. The first one is to use digital labeling solutions that eliminate the need for physical labels. These digital labels can be implanted inside product packages or via their display technology, decreasing total material consumption. Manufacturers are also shifting towards reusable labeling solutions, wherein the labels can be applied, removed, and used multiple times, curtailing waste generation.

Smart labeling and RFID and NFC tags are other technologies that help reduce the need for printed materials. Because these tags can be used on multiple products, the need for traditional paper or plastic labels and packaging waste is decreased. Digital and smart labels can be printed using eco-friendly, recyclable materials that will reduce environmental impact at the end of the manufacturing process (Horvath & Geller, 2019). They have adopted sustainable labeling systems because they will aid manufacturers in attaining environmental goals and increase the extent to which they can comply with growingly stringent regulatory requirements regarding waste reduction and recycling.

10.5 Predictive Maintenance for Labeling Equipment

Reliability of labeling equipment also remains another factor in labeling accuracy, aside from addressing mislabeling errors caused by human error. Predictive maintenance technologies, supported partly by sensors and data analytics, offer a promising solution to the inevitable labeling issues stemming from faulty equipment or machine failure. Predictive maintenance systems monitor the performance of the labeling machines in real-time and measure temperature, vibration, and operating speed in time. Analysis of this data is then used to predict when it is most likely that a machine will fail or need servicing (Daily & Peterson, 2016). Manufacturers can prevent any downtime on their labeling systems and reduce the risk of mislabeling due to faulty machinery by proactively addressing equipment issues before they occur. It helps improve labeling accuracy and the overall efficiency of processes to reduce unplanned maintenance and the associated high-cost repairs. The need for predictive maintenance is increasing as label machines improve, and there is an important practice for having high-quality labels.

10.6 Global Standards for Labeling Systems and Traceability

With the global nature of the manufacture and circulation of goods across international boundaries, the importance of establishing global standards for labeling and traceability increases. The labeling and traceability requirements for items in various industries and countries still differ, resulting in inconsistency and a high risk of mislabeling. A couple of manufacturers may live in different regulatory regimes, but harmonizing labeling standards globally allows manufacturers to simultaneously reduce the complexity of fulfilling all the regulatory frameworks (Pekdemir, 2018). This will help manufacturers standardize labeling practices so that their products will comply with the requirements of other markets, thereby improving efficiency and compliance. This would also make these global standards applicable to the seamless integration of future technologies like RFID and AI and would help manufacturers in any part of the world enjoy the different features that such labeling systems will have. International standards of product labeling will also contribute to enhancing product traceability in products like automotive and pharmaceuticals because of the importance of the product's integrity. Clear and consistent labeling requirements will allow product tracking to prevent mislabeling issues from kicking up and impacting the consumer or end user.

11. Conclusion

Mislabeling in manufacturing is an issue that can result in significant operational inefficiencies, increased costs, and safety hazards. From an automotive company Supplier Industrialization Internship, the case study provides insight into the professional impact of mislabeling on production and the final product’s quality. This paper demonstrates the significance of utilizing data-driven decision-making to understand the root causes of the mislabeling and what needs to be done in the form of corrective and preventive actions to ensure these issues are resolved efficiently. It was found that human error contributed significantly to mislabeling, with cracks in interpersonal communication and in printing, scanning, and applying labels. The company implemented such corrective actions as limiting label printing, dual scanning for verification, and improved operator training towards better-practicing labeling standards. Automation, real-time tracking systems, and advanced data analytics were necessary to move Sauce to a more accurate and efficient labeling practice. The technologies also enabled the company to promptly identify errors, control risks, and prevent labeling issues from becoming more serious.

The case study also revealed an important aspect of creating an organizational culture dedicated to quality and continuous improvement. Since congestion encourages employees to find and solve labeling problems, it discourages mislabeling. A great part of the role was to apply Lean Manufacturing principles and Six Sigma methodologies to reduce waste in labeling processes and preserve labeling accuracy at all levels of the organization. The paper draws attention to the role of supplier management strategy in mitigating mislabeling risks. Regular audits and improvements with suppliers go a long way towards ensuring that manufacturers get consistent labeling from their suppliers through clear communication. Data sharing between manufacturers and suppliers can also help identify causes and trends of mislabeling and potentially find better solutions. Also, using advanced labeling technologies like RFID and QR codes will improve product traceability and drastically reduce labeling errors; each product will always be properly identified until it reaches the customer.

The future of this industry in addressing mislabeling in the manufacturing sector lies in the continuous integration of emerging technology, Artificial Intelligence (AI), Augmented Reality (AR), and predictive maintenance.

These technologies could enable additional optimization of labeling processes, reduce human error, and enhance operational efficiency. Since an AI-powered system can analyze huge amounts of production data to predict and avoid labeling errors, AR provides the operators with immersive training and real-time feedback. Predictive Maintenance systems can also monitor label equipment and proactively react to potential failures before mislabeled products are produced. To solve the mislabeling problems at the manufacturing stage, a gateway to solving problems is to combine advanced technology, data-driven decision-making, and continuous improvement strategy. A case study from an example of an automotive company proves that implementing these practices can substantially reduce risks preconditioned by mislabeling, boost product quality, and improve overall operational efficiency. Labeling systems are always created to assure the quality and safety of products. Automotive manufacturing is one of the most important industries, where precision and safety are extremely important.

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